PLEASE READ AND FOLLOW THE DIRECTIONS ON HOW TO WRITE A DESCRIPTION OF YOUR INVENTION

Please attach a page to this form, DATED AND SIGNED BY AT LEAST ONE PERSON WHO IS NOT A NAMED INVENTOR, to provide a description of the invention, and include the following information:

1. Describe in detail what the components of the invention are and how the invention works.

2. Describe advantage(s) of your invention over what is done now.

3. YOU MUST include at least one figure illustrating the invention.

5. Identify the closest or most pertinent prior art that you are aware of.

6. Who is likely to want to use this invention or infringe the patent if one is obtained and how would infringement be detected?

***HAVE YOUR SUPERVISOR READ, DATE AND SIGN COMPLETED FORM**

DATE: [redacted] SUPERVISOR: ____________________

BY THIS SIGNING, I (SUPERVISOR) ACKNOWLEDGE THAT I HAVE READ AND UNDERSTAND THIS DISCLOSURE, AND RECOMMEND THAT THE HONORARIUM BE PAID

EXHIBIT A

Haptic Rendering Device

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1. Describe in detail what the components of the invention are and how the invention works.

This disclosure describes a new rendering device. More specifically, a device used for rendering haptic output. It allows the user of our haptic rendering device (HRD) to *feel* the texture of an environment or *touch* another person's hand that lives on the other side of the continent. It also empowers the blind to have the ability to read web pages, imagery, boldface and italic text, etc. We describe this apparatus in detail below. When we use the term *render* we mean this in the same spirit that a computer graphics pipeline renders an image to a framebuffer. Similarly, we will *render* a set of values to an array of memory that is used by the haptic rendering device to set the state of each element.

We propose a collection of haptic rendering elements, called *haptels*, used for rendering the content of a memory buffer. The haptels can be constructed in any number of ways. For example, we are exploring a device that uses a substance inside a piston that expands to push pins [1,2]. A circuit that can address each individual haptel stimulates the substance, enclosed in a very small cylinder that sits underneath the pins. The pins are then stimulated to move in real-time a distance proportional to the amount of current applied.

A key technical challenge in building an HRD is 'how do we drive each individual haptic element?', especially while containing the device which drives the element in an extremely small space. While many options exists, we are currently determining which will be most appealing for its ease of construction, reliability, scalability, mechanical simplicity, and when produced in volume, its cost per unit, several of the things at which Intel Corporation is an industry leader. Because we are using current to drive the device, we have analog control over the amount of current applied to each element. This assists in calibration of the device as well as giving us great flexibility as to how much each haptel moves.

Several other methods to drive the device exist. For example, hydraulics could be used where a compressed liquid drives each element. Another method is to create a magnetic current for each haptel by running wire around the region of each haptel and drive it by charging the coil. This method is appealing because there will not be interference between each haptel, a necessity when they are in such close proximity to one another. Another method would be to use small motors to drive each haptel up and down. While this one may be unreasonable today, nanotechnology is progressing rapidly and its effective application to building small motors has already hit pedestrian literature).

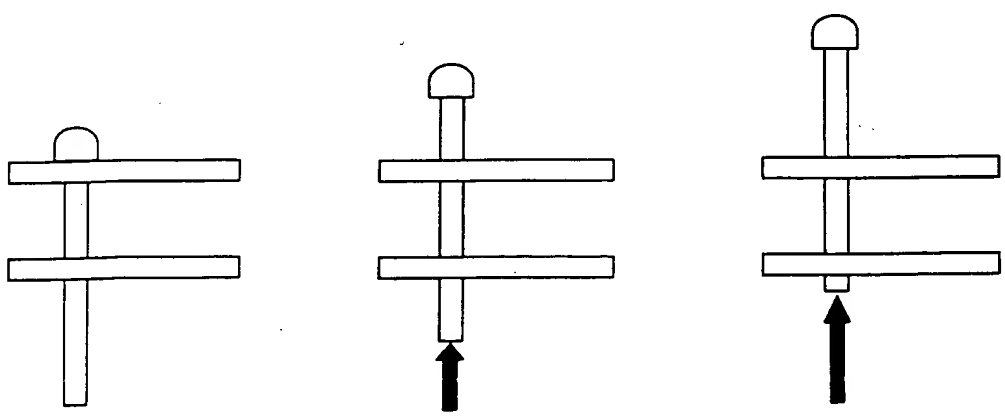

Figure 1. In this figure a single haptel is being shown as it moves up depending on the amount of force used to push on the individual element.

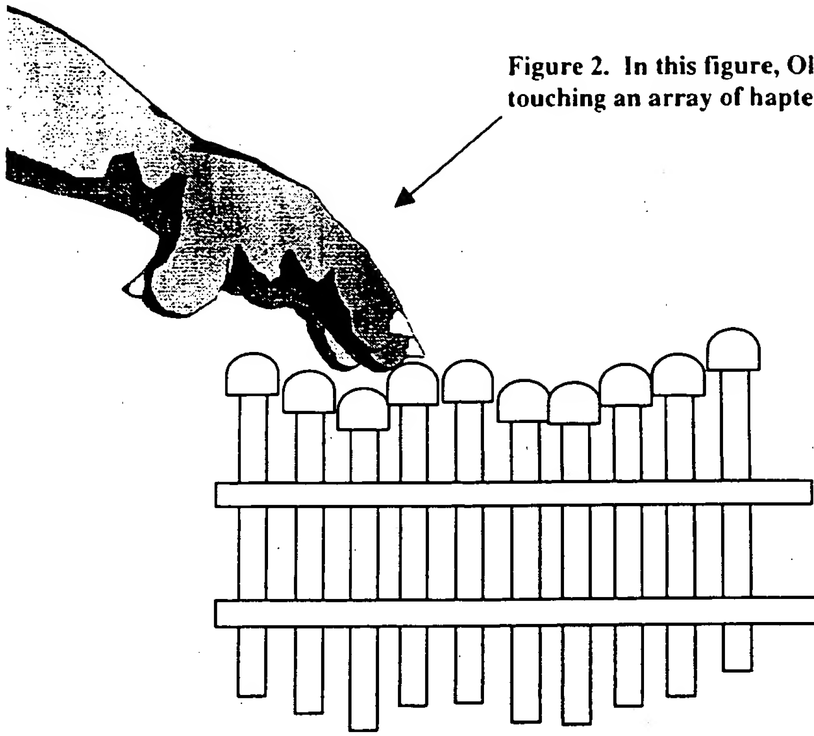

Figure 2. In this figure, Olaf is touching an array of haptels.

When a group of haptel elements are placed close together, as in the figure above, we are able to dynamically, and in real-time, address the HRD. A user can then see and more importantly ***feel*** the surface of the rounded haptels. The surface can change relative to the dance of a virus in a scanning electron microscope[1] or the discrete gray scale values in an image. It can also be raised to different levels to symbolize bold or italic text from a web page, document ,spreadsheet, etc. However, most interesting is the ability to use the device to communicate via telepresence with another person that may not be located anywhere near the HRD, your best friend, your wife, your children. Imagine if you will that we read their input via a pressure sensing tablet or another HRD. That input is then sent over the WAN to your home PC. Your home PC unpacks the data and updates the HRD to reflect the new information. The amount of data for a full HRD update is equivalent to a gray scale image with the same number of pixels as the HRD has haptels. This is a trivially small amount to send over the wire currently and even moreso with higher bandwidth Internet connections and modern compression techniques.

This device is about bringing people closer together using the Internet. Away on your business trip you can now call home, reach out and *really* touch someone....virtually.

As of today, there is no device similar to ours. The closest thing that has come to mind is the computer controlled binary devices for reading Braille. Each of these devices relies on the computer to send a signal to a small needle that can be in one of three positions. The needles are placed sufficiently apart such that they do not have to deal with one of the technical challenges our device necessitates: how to control a number of haptel elements in a small region of space. Ideally, each of our elements is touching or has an absolutely MINIMAL amount of space between elements. We want a user to feel as if what they are feeling is the actual surface, for example another persons

hand.

In addition, the degree of movement is at least 10 times smaller. We desire movement on the order of centimeters (say 4-8 in first iteration devices). The above mentioned Braille device focuses on movement measured in millimeters.

To the best of our knowledge nobody has considered the use of these devices for I/O with the exception of a Braille output mechanism. People simply have no cost effective way to communicate haptically.

Input to the device can be done using a another device of similar construction that can act as a 'reader'. A simpler idea would be that of a simple pressure pad that could read the amount of relative pressure applied to a flat surface. One can rather easily envision an HRD I/O device capable of both rendering and registering pressure—

As already mentioned, we hope for people to use the device to communicate with one another. We also hope to see it used as an improved visualization device for the blind, and as a new I/O device for games. Imagine walking up to a door, and near the door are 3 custom buttons. You see them on the screen, and when they intersect with the view frustum of the user, up pops the 3 buttons on the input device. Now, the user reaches over and actually PUSHES on the button on the HRD!

Yet another use that has been discussed is for CAD designers to be able to actually visualize the 3D geometry of the object they are working on. The first devices constructed will only be able to show the 2D projection of the object on the screen, but now they are able to see it with depth! So, as they spin the object on the screen, the haptels react accordingly. A final use is the ability to read the level of the haptels and use this information to reconstruct the 3D geometry of the object pressing on the surface. Obviously for a truly 3D object all facets of the object would need to be exposed to the device, then user guided reconstruction could take place. Automation of a task similar to this is still considered a technical challenge but the computer vision and graphics literature is filled with techniques for surface reconstruction.

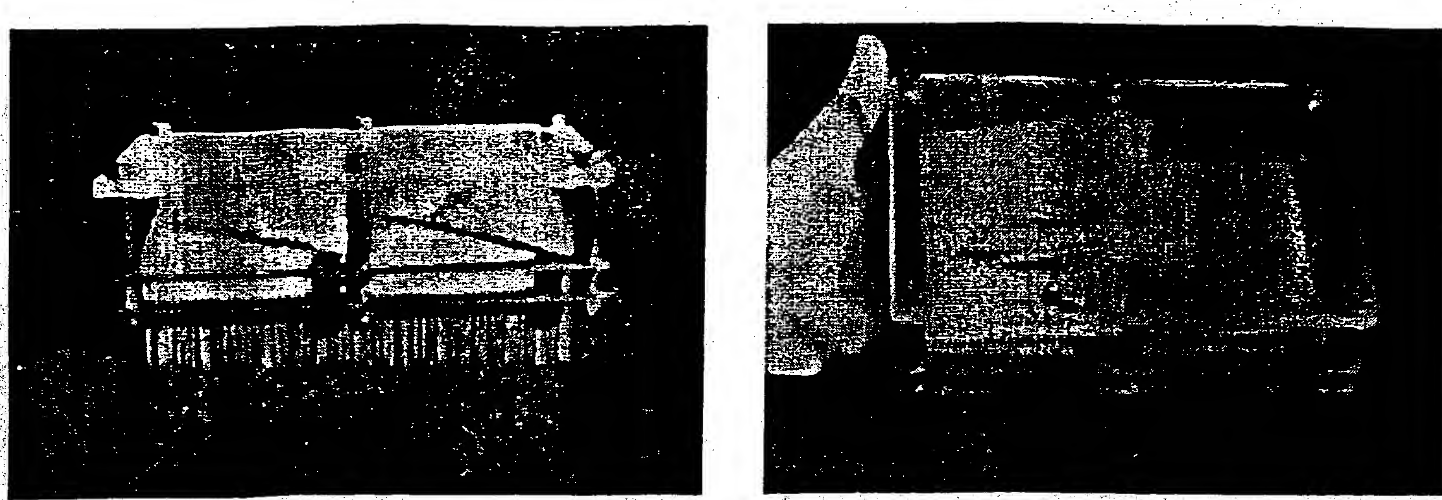

Figure 3. A device that could be considered a manual HRD. On the left, the device is laying on a road reflecting the terrain underneath it. On the right is the device representing a hand. Our proposed device will be stimulated electronically and be able to be used over WANs to render identical representations of pavement, hands, or other stimuli.